6p

X63-11436
Code 2d

NASA TT F-8353

INVESTIGATION OF A D-C ARC AT INCREASED PRESSURE

by A. N. Zaydel', A. G. Zhiglinskiy, and E. A. Karklina

Translation of "Issledovaniye dugi postoyannogo toka pri povyshennom davlenii."
Izv. Akad. Nauk SSSR, ser. fiz., Vol. 26, No. 7, 855-7 (1962).

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON January 1963

INVESTIGATION OF A D-C ARC AT INCREASED PRESSURE

A. N. Zaydel', A. G. Zhiglinskiy, and E. A. Karklina

A number of authors [1-3] have pointed out the important role played by diffusion processes in the removal of atoms from a discharge zone. In [4] an attempt was made to explore the possibility of increasing the sensitivity of spectroanalytical determinations in a d-c arc at increased pressure. The setup employed has already been described [4]. /855

Fig. 1 shows photographs of the spectrum of lithium, excited at carbon dioxide pressures of 1 and 7 atmospheres. It is clear from the spectrogram that when the pressure is increased the lithium and copper spectrum becomes more intense. The increase in pressure was also accompanied by an increase in the sample burn-up time, so that the integral $\int_0^t I dt$ (where t = burn-up time, I = intensity of line Li I 6103) is nine times greater. The relative intensity of the lithium line with respect to the background increases 11 times. It should be noted that in studying the spectra of other elements it is usual to observe a certain increase in the continuous spectrum with increasing pressure.

Fig. 2 shows the intensity of the lines of a number of elements plotted against pressure. These elements formed a few percent of the composition of copper-based alloys. The investigation was concentrated on the lines recommended in [5] for analytical purposes. It is noteworthy that the copper lines Cu I 5292 Å and Cu I 5782 Å with different excitation potentials 7.74 and 3.79 ev) [6] increase in intensity to the same extent. The spectra of iron-based alloys do not develop a significant effect (only 1.5 to 2 times), like the spectrum for iron present in copper in the form of an impurity (except for the line Fe I 3175, for which a sevenfold increase in intensity was observed, Fig. 2). /856

We studied the roles of various factors affecting the intensity of the lines in the arc with the spectrum of the lightest element Li, for which the relative part played by

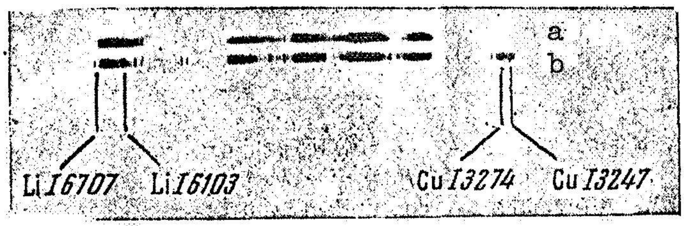

Fig. 1. Photographs of spectrum of arc at atmospheric pressure (a) and at a pressure of 7 atm (b). Lithium introduced into crater of carbon cathode. Copper anode. Discharge current 6 amps.

diffusion in the process of removal of atoms from the discharge zone ought to be most important.

An increase in pressure is accompanied by a pinching of the discharge [7]. In order to determine the degree of contraction of the discharge, an image of the arc, turned through 90° with the aid of a system of mirrors, was projected onto the inlet slit of a spectrograph. Hörmann's method [8] was used to convert the intensity distribution found experimentally to the radial. From the curves obtained it followed that when the pressure was increased to 7 atm, the half-width of the radial intensity distribution diminished about 1.9 times. The volt-ampere characteristics of the arc for 1 and 7 atm practically coincided, which is in accord with the data of [9,10].

The concentration of atoms in the discharge depends both on the processes of removal and the processes of supply of matter. In studying the rate of supply it proved that the rate of evaporation of lithium from the cathode crater and the amount transferred to the anode varied little with increase in pressure.

From the above it is clear that on increasing the pressure in the arc we must expect an increase in the temperature of the plasma. A study of the temperature in the peripheral parts of the discharge, where lithium is brightest, is best carried out with the aid of lithium lines. We measured the temperature from the relative intensity of the lines Li I 6103 and Li I 6707. Since it is difficult to free the Li I 6707 line from self-absorption, it is convenient to use Sobolev's method [11] of determining

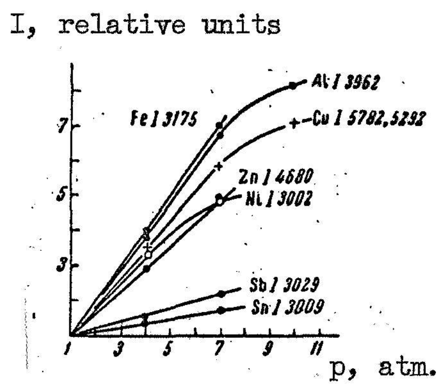

Fig. 2. Variation of relative intensity of spectral lines of several elements with increase in the pressure in the arc.

the temperature in the event of large optical thicknesses of the radiating layer. In this connection we were obliged to make two further assumptions: 1) that for the lines investigated the ratio of the effective cross sections for collision of a radiating atom with molecules of the discharge carrier does not depend on the pressure, and 2) that the optical thicknesses of the layers absorbing the 6103 and 6707 Å lines are equal. The latter is convincing in the light of the data of [12].

The relative intensities of these lines were measured for the concentration of lithium in the discharge at which the intensity of the two lines varied as the square root of the concentration of lithium in the sample.

Results of measurements: $\frac{1}{T_1} - \frac{1}{T_4} = 2.8 \cdot 10^{-5}$ degrees $^{-1}$ and $\frac{1}{T_1} - \frac{1}{T_7} = 3.6 \cdot 10^{-5}$ degrees^{-1}, where T_1, T_4, T_7 = temperatures of the discharge at 1, 4, and 7 atm, respectively. This change in temperature should produce 3.5- and 5-fold increases in the intensity of the Li 6103 line.

A decrease in intensity ought to result from contraction of the discharge (due to decrease in the thickness of the radiating layer and decrease in the diffusion lifetime of atoms in the discharge zone [1]). The effect of a number of other factors (degree of ionization, magnitude of radial field) on the intensity of the source is still difficult to estimate. /857

The data obtained give us reason to suppose that the light source previously proposed [4] may prove to be promising for increasing the sensitivity of spectroanalytical determinations and merits extensive investigation.

LITERATURE CITED

1. Raykhbaum, Ya. D. Spektral'nyy analiz v tsvetnoy metallurgii (Spectral Analysis in Nonferrous Metallurgy). Collection of articles, Metallurgizdat, 1960.
2. Mandel'shtam, S. L. Optika i spektroskopiya (Optics and Spectroscopy), Vol. 10, 398, 1961.
3. Zaydel', A. N., Kaliteyevskiy, N. I., Kund, G. G. & Fratkin, E. L. Optika i spektroskopiya, Vol. 2, 28, 1957.
4. Zhiglinskiy, A. G., Zaydel', A. N. & Karklina, E. A. Optika i spektroskopiya, Vol. 10, 697, 1961.
5. Mandel'shtam, S. L. & Rayskiy, S. M. Tablitsy spektral'nykh liniy (Tables of Spectral Lines), Gostekhteorizdat, 1938.
6. Zaydel', A. N., Prokof'yev, V. K. & Rayskiy, S. M. Tablitsy spektral'nykh liniy (Tables of Spectral Lines). GITTL, (State Publ. House of Technical and Theoretical Literature), 1952.
7. Kaptsov, N. A. Elektricheskiye yavleniya v gazakh i vakuume (Electrical Phenomena in Gases and in a Vacuum), 1950.
8. Hörmann, H., Z. Phys., 97, 539 (1935).
9. Suits, C. G., J. Appl. Phys., 10, 203, 728 (1939).
10. Suits, C. G., Phys. Rev., 55, 561 (1931).
11. Sobolev, N. N. Tr. FIAN (Proc. Phys. Inst. Acad. Sci.), Vol. 7, 159, 1956.
12. Podmoshenskiy, I. V. Optika i spektroskopiya, Vol. 9, 281, 1960.

DISCUSSION

V. I. Mosichev. If we neglect convection, then the increase in the intensity of the lines due to a diminution in the diffusion of atoms from the discharge cloud ought to be proportional to the pressure. However, according to the Kramers-Unsöld theory, there is a simultaneous increase in the intensity of the continuous spectrum, due to recombination of ions and electrons. Therefore, in the general case, it is difficult to anticipate a significant increase in the ratio I_λ/I_Φ with increase in pressure. Our preliminary experiments with a d-c arc in the range of gas pressures (Ar, N_2, CO_2) from 1 to 100 atm confirm the correctness of these remarks. The increase in the ratio I_λ/I_Φ, obtained for Li by the authors of the article, is apparently a special case and conditioned by a decrease in the intensity of the molecular spectrum.

FARADAY TRANSLATIONS
15 PARK ROW
NEW YORK 38, N. Y.